

Digital Elevation Models of Bellingham, Washington: Procedures, Data Sources, and Analysis

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Summary

In September of 2017, NOAA's National Centers for Environmental Information (NCEI) developed topographic-bathymetric digital elevation models (DEMs) of Bellingham, Washington (Figure 1) for NOAA's National Tsunami Hazard Mitigation Program (NTHMP). The 1/9 arc-second tiled DEMs will be used to support improving the coastal tsunami inundation forecasts, storm surge modeling, community preparedness and hazard mitigation. These DEMs cover the coastal area of Bellingham, Washington. The extents of this DEM, procedures, data sources, and analysis are described below.

The Bellingham, Washington DEMs cover the area surrounding the city of Bellingham, Washington and the Eastern San Juan Islands (Fig. 2).

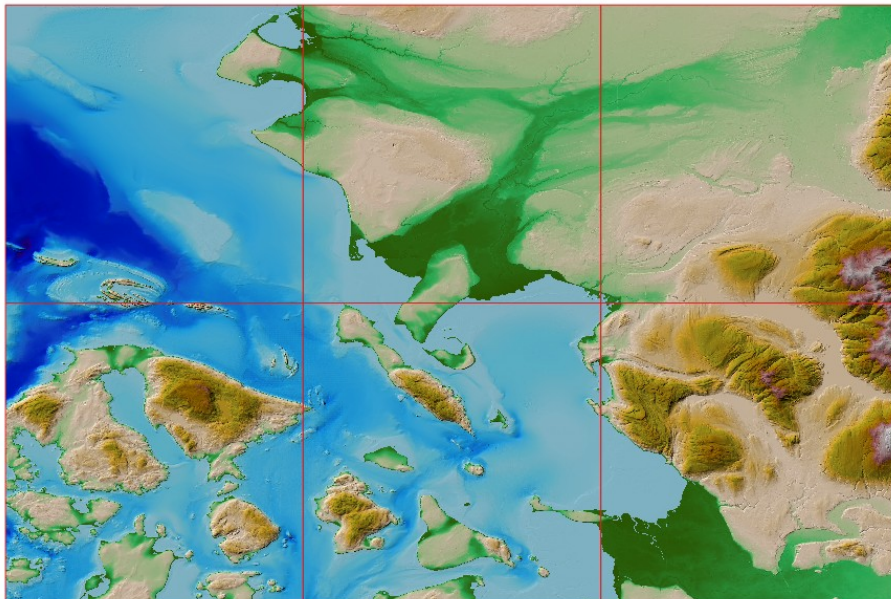


Figure 1. Bellingham, Washington Tiled Digital Elevation Models

DEM Specifications

The Bellingham, Washington DEMs were built to the specifications listed in Table 1. Figure 2 shows the 1/9 arc-second tile boundaries in red. The best available digital data were obtained by NGDC and shifted to common horizontal and vertical datums: World Geodetic System of 1984 (WGS 84) and National Vertical Datum 1988 (NAVD88). Data were gathered in an area slightly larger (~5%) than the DEM extents. This data “buffer” ensures that gridding occurs across rather than along the DEM boundaries to prevent edge effects. Data processing and evaluation, and the DEM assembly and assessment are described in the following subsections.

Table 1. Specifications for the Bellingham, Washington DEM.

Grid Area	Bellingham, Washington
Coverage Area	-123.0° to -122.25° W, 48.5° to 49° N
Coordinate System	Geographic decimal degrees
Horizontal Datum	World Geodetic System 1984 (WGS 84)
Vertical Datum	National Vertical Datum 1988 (NAVD88)
Vertical Units	Meters
Cell Size	1/9 arc-seconds
Grid Format	Tiled ASCII raster grids

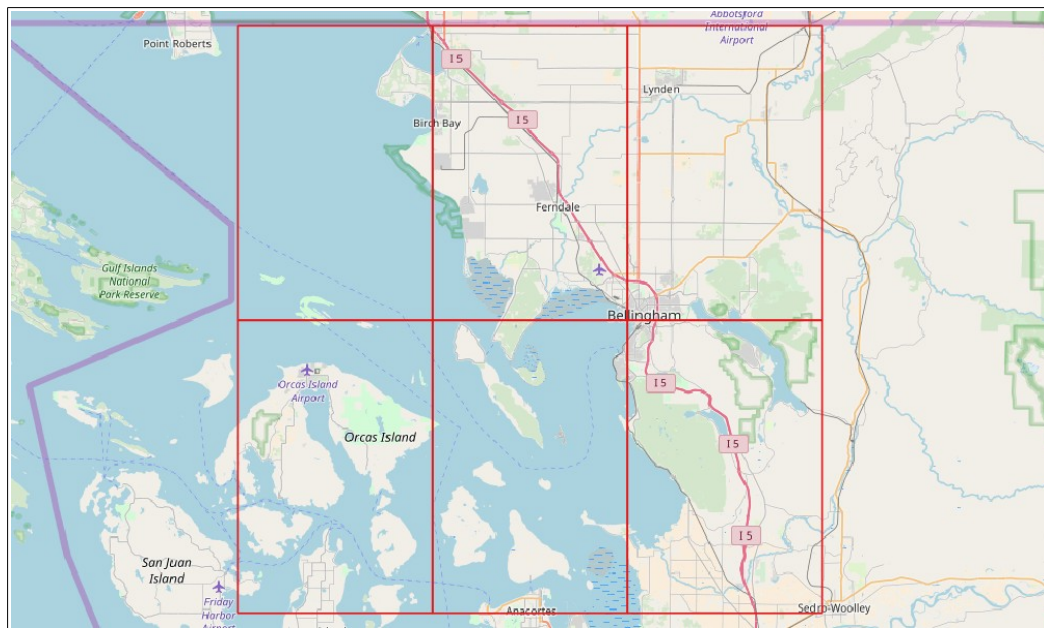


Figure 2. Map image of the DEM boundary for the Bellingham, Washington. DEM in red.

Data Sources and Processing

The digital coastline used in developing the Bellingham, Washington DEMs was generated by editing the Global Self-consistent, Hierarchical, High-resolution Geography Database (GSHHG) shoreline based on the Google satellite imagery layer. The digital coastline was converted into a polygon for use in masking topography and eliminating interpolated data.

Bathymetric data used in the compilation of the Bellingham, Washington DEMs included sounding data from the National Oceanic Survey (NOS) as well as completed datasets from NCEI (Table 2).

Topographic data used in the compilation of the Bellingham, Washington DEMs included lidar data obtained from NOAA's Office of Coastal Management (OCM) and the Washington State Department of Natural Resources (WADNR).

Table 2: Bathymetric and Topographic Data Sources used in compiling the Bellingham, Washington DEM.

Source/Title	Date	Data Type	Resolution	Horizontal Datum	Vertical Datum
PSLC Lidar: North Puget Sound Lowlands	2005	Topographic Lidar	< 1 meter	WGS84 Geographic	NAVD88
USGS BE Lidar: North Puget Sound (WA)	2006	Topographic Lidar	< 1 meter	WGS84 Geographic	NAVD88
PSLC Lidar: San Juan County	2009	Topographic Lidar	< 1 meter	WGS84 Geographic	NAVD88
PSLC Lidar: Nooksack	2013	Topographic Lidar	< 1 meter	WGS84 Geographic	NAVD88
USACE USGS Topobathy Lidar: Puget Sound (WA)	2014	Topographic Lidar	< 1 meter	WGS84 Geographic	NAVD88
City of Bellingham Lidar	2013	Topographic Lidar	< 1 meter	WGS84 Geographic	NAVD88
NOS BAG	2010	Bathymetric Soundings	1 – 10 meters	WGS84 Geographic	Mean Lower Low Water (MLLW)
NOS Hydro	1930 - 2010	Bathymetric Soundings	1 meter to several kilometers	WGS84 Geographic	MLLW
NCEI Port Townsend, WA DEM	2015	Topographic/Bathy metric DEM	10 meters	WGS84 Geographic	NAVD88

The bathymetric data were transformed from their original datums to a horizontal datum of WGS 84 and a vertical datum NAVD88 prior to DEM development using vertical transformation parameters provided by NOAA's Vdatum software. Topographic data were transformed from their original horizontal datums to a horizontal datum of WGS 84. All topographic data originated in NAVD88 prior to development, so no added vertical transformations were needed.

DEM Development

After the bathymetric data were transformed to common horizontal and vertical datums, they were visually reviewed for consistency and errors. Where more recent, higher resolution bathymetric data existed, older data were superseded. The edited and evaluated bathymetric data were then converted to ASCII xyz format using GDAL then gridded at 1/9 arc-second using Generic Mapping Tools (GMT). The GMT 'surface' tool was used to generate a bathymetric surface which provided full data coverage of the DEM area. The surface was then clipped using the digital coastline to create the final bathymetric DEM. The final bathymetric DEM was then converted to ASCII xyz format for use as input in generating the final DEM.

After the topographic data were transformed to common horizontal datums, the areas of overlap were visually reviewed for consistency and errors.

MB-System was used to create the 1/9 arc-second Bellingham, Washington DEMs. MB-System is an NSF-funded open source software application specifically designed to manipulate submarine multibeam sonar data, though it can utilize a wide variety of data types, including generic xyz data. The MB-System tool 'mbgrid' was used to apply a tight spline tension to the xyz data, and interpolate values for cells without data. The data hierarchy used in the 'mbgrid' gridding algorithm, as relative gridding weights, is listed in Table 3. The resulting binary grid was converted to an Arc ASCII grid using the GMT tool 'grdreformat' to create the final 1/9 arc-second Bellingham, Washington DEMs.

Table 3: Data hierarchy used to assign gridding weight in MB-System

Data-set	Relative Gridding Weight
Generated Bathymetry Surface	10
Lidar datasets	100
NOS BAG Data	100
NOS Hydrographic Data	1
NCEI DEMs	.1

Recommendations

Recommendations to improve the Bellingham, Washington 1/9 arc-second DEMs are listed below:

- Conduct bathymetric lidar surveys of near-shore coastal and marsh areas.
- Conduct high-resolution bathymetric surveys of all inlets and bays.

References

Lim, E., L.A. Taylor, B.W. Eakins, K.S. Carignan, R.J. Caldwell, P.R. Grothe, and D.Z. Friday, 2012. Digital Elevation Models of Port Townsend, Washington: Procedures, Data Sources and Analysis, NOAA Technical Memorandum NESDIS NGDC-60, U.S. Dept. of Commerce, Boulder, CO, 36 pp.

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